Burden sharing between actors: allocating "economic bads" in Europe's refugee crisis

Akbota Anuarbek, Gergana Markova

Duke University

Abstract

This paper aims to offer allocation mechanisms for burden sharing of refugees between different states. Three main characteristics of the mechanisms that we look at are their truthfulness, efficiency, and whether or not they are budget balanced. While we are unable to offer a mechanism that satisfies all three of them, we offer a model that, after the assumption of a limited budget is relaxed, offers a strategy proof and efficient allocation by using VCG payments, and another one using a Vickrey auction that offers a strategy proof and budget balanced distribution mechanism, but is less efficient. We also propose a matching algorithm that allocates refugees to the already established quotas by country in order to maximize utility for both the refugees, and the EU member states.

Keywords: burden sharing, VCG, Vickey auction, allocation mechanisms

1. Introduction

Recent instability in the MENA region has brought a refugee influx crisis among European Union countries. The nature of the European Union, based on the idea of burden sharing and free movement of people, goods, and capital, has pushed the EU to come up with a mechanism of allocating the incoming refugees among not simply the countries of entry, but all member states. Each refugee is associated with a certain cost per country: social welfare needs to be provided by the state, and once the refugee is issued a working permit, there is still some cost on society that refugees impose in terms of integration; therefore a burden sharing mechanism needs to be designed to resettle the refugees among all member states. The current allocation mechanism uses a *distribution key* that captures the country's capacity to absorb and integrate refugees based on macroeconomic factors such as total GDP as a proxy for the wealth of the country, size of the population, average number of applicants, and unemployment rates, to establish quotas of refugees per country. We argue that this is not the most efficient allocation mechanism, and that it does not capture the differences in refugee cost functions per country. A more effective mechanism would be one that distributes the refugees by accounting for countries' specific preferences, thus maximizing the total utility for the EU (or minimizing the total incurred cost). We therefore attempt to design a mechanism that considers refugees as *economic bads* and assumes states are rational utility-maximizing actors; such mechanism would allocate refugees to the countries with the lowest costs and in the process will reveal their cost functions and thus determine a fair and truthful price per refugees per country. We also propose the use of different matching algorithms that take into consideration the countries' preferences for types of refugees (in terms of nationality, gender), and the refugees' ranking of countries they would like to settle in, to maximize both the countries and the refugees' utilities.

The resettlement mechanism would be ideally one that is at the same time strategy proof, efficient, and budget balanced. However, due to the complicated nature of cost sharing problems, finding a mechanism that satisfies all three of these requirements has proven to be a task beyond the scope of this paper. As such, we first propose a two-step allocation process that is budget-balanced and strategy proof, but not necessarily efficient, and then a VCG mechanism during which all countries reveal at the same time their cost functions, which we argue is truthful and efficient, but not budget balanced.

The paper first provides a review of the relevant literature on the issue, then explains in depth the proposed resettlement mechanisms, provides an overview of matching algorithms that can be used to match refugees with member states, and concludes by summarizing the paper and its findings.

2. Literature Review

While the problem of refugee allocation and burden sharing has been widely studied in the social science literature, few have attempted to offer a computational mechanism that minimizes the cost of sharing or incentivizes actors to reveal their true cost functions and thus establish the true cost of the burden. An attempt to improve the efficiency of the current method of resettlement employed by the European Commission by using market mechanisms has been made by Mortaga [1]. They propose a model in which, after countries have been distributed their initial quotas of refugees using the current EU distribution key, they are allowed to trade quotas. After the trading is done and the final quotas are allocated, they offer a matching mechanism to match refugees to countries. However, the limitations of this model lie in the fact that countries are already assigned quotas that are not a fair representation of their costs before they start trading. Countries with high costs due to high social costs, which are not included in the EU distribution key, rather than economic costs then might be allocated too high of a initial quota; then they will enter the market by already being put at a disadvantage and this might influence the final outcome. The trading quotas mechanism will also impose extra costs in terms of both time and capital on the countries, as they will need to keep trading until an efficient outcome has been achieved.

In the computational economics literature, some research has been done mainly on different mechanisms for allocating economic "bads" or cost sharing between actors. Main desired qualities of such mechanisms are truthfulness, efficiency, and budget balancing. The paper that explores an issue closest to the one we are studying analyzes how individual rationality would affect optimality when using VCG to assign economic bads[2]. Due to the specificity of the bads we need to allocate however, and the nature of the particular situation, many of the assumption taken by You will not be applicable when we look at refugees. In his paper, You talks about actors trying to allocate negative identical tasks between them, with the tasks being strictly less than the number of people. Our model has no constraint on the total bundles of refugees being auctioned, but rather on the total amount of refugees. The bundles are also not identical, in order to capture the increasing marginal cost of taking more refugees. Moreover, something of importance of You's analysis is the ratio between tasks and people; an analogy between this and the refugee problem would be hard to make. We then try to contribute to the literature by developing a VCG mechanism, and a second price auction that will allocate bads of as of a specific nature as refugee: non-identical and with increasing marginal cost. This will also be a contribution to the literature in the field of social sciences, as such problems are often discussed there from a less computational perspective, and thus often lack a certain level of efficiency.

3. The Model

The problem of efficiently allocating refugees among the EU member states is described in the following way. At some particular point in time there are N refugees that need to be allocated among M European Union member states. Each refugee is considered as an "economic bad", because allocating a refugee is costly for a country. Thus, every country has a cost function associated with the number of refugees it will be hosting. This is a reasonable assumption, since countries have limited capacity and resources. Cost functions are assumed to be increasing with increasing marginal costs for all countries. Hence, the marginal cost of allocating every additional refugee increases with the number of refugees already allocated. We do not put any other assumptions on cost functions, in fact they may be different across different countries. Moreover, all member states are assumed to behave in a rational way and maximize their total utility. Finally, the EU has a budget that it uses to compensate its member states for hosting refugees.

The objective is then to allocate refugees among countries that have the lowest costs of hosting refugees among the EU member states. This problem of efficiently allocating refugees can be solved in two steps. In the first step refugee quotas are established for each state. This step is addressed in more detail in the next section by describing and analyzing different allocation mechanisms. Once the decision about the number of refugees to be allocated in each member state is made, the next step is to actually match refugees to countries. This step is implemented in section 5 by taking into consideration preferences of countries and refugees and other important issues.

4. Establishing Quotas per Member State

4.1. Repeated Vickrey auction

One mechanism for establishing refugee quotas is "trading" a bundle of refugees at a time. To make the mechanism less tedious refugees can be split into bundles, for example of size 10 or 100. Because the total number of refugees is very high and costs imposed by one refugee is insignificantly small doing this does not rise efficiency problems. Let us assume there are N refugee bundles that need to be allocated among M countries. Then at every iteration of the mechanism second price (Vickrey) auction is implemented, where each country is a bidder and bundles of refugees are considered to be identical goods. However, since refugees are assumed to be "economic bads" rather than being goods, countries need to be compensated for receiving a bundle of refugees as opposed to paying for receiving a good as in a usual second price auction. The winner will be the one who bids the lowest amount and is compensated by the amount of the second lowest bid. The mechanism will be terminated, when all the refugees are allocated.

This mechanism is *strategy proof*, because bidding truthfully is optimal in this case. At every iteration i of the mechanism country j will bid

$$b_{i,j} = c(n_j + 1) - c(n_j) \tag{1}$$

which is its true marginal costs for allocating an extra refugee. n_j is the number of refugees country j already has. If a country has the lowest bid, it will be compensated at least by the amount $b_{i,j}$, thus no country wants to bid an amount higher than their true marginal cost. There is also no reason for a state to bid anything lower than its true marginal cost, because if its bid is accepted that country may incur negative costs. The mechanism also *efficiently allocates refugees*, because it allocates them among the countries that have the lowest costs for hosting a refugee. At each iteration a bundle of refugees is sent to the country with the lowest marginal cost. Thus, total costs of allocating all the refugees is minimized. However, the mechanism is *not budget balanced*. Extra source of fund is needed to compensate countries for allocating refugees to the countries. This may be done using the EU fund, and in fact European

Union has a fund it uses to at least partially compensate countries for hosting refugees. However, if the amount of the budget is limited, it may not be enough to allocate all the refugees by the proposed mechanism. We attempt to address this issue in the following section.

4.2. Repeated Vickrey auction with uniform redistribution

This mechanism runs the repeated Vickrey auction for "economic bads" described above until the limited budget is exhausted. Once the budget is exhausted remaining refugees are distributed uniformly among all the countries. We assume there is an imperfect information in the game. While the mechanism is running countries are not informed about the amount of the remaining budget, which implies that at each iteration of the auction countries do not know if the current iteration is the last one. Only after the budget becomes exhausted they are informed about it and receive their 'portion' of the remaining refugees. This problem can be viewed in a following way without actually changing the problem, but by making the reasoning much easier.

Suppose all N bundles of refugees are initially distributed uniformly among M countries. To make the following explanation more intuitive assume there are M refugees in each bundle. Then at each iteration, the mechanism collects a bundle by taking one refugee from each country and auctions the bundle using the Vickrey auction. The process will stop either when the budget is exhausted or when countries no longer have any more of those refugees that were initially distributed to them, i.e. all the refugees that countries will have are the ones allocated to them by the Vickrey auction (this is equivalent to the case when all the refugees are allocated and the amount of budget was enough to allocate all of them in the previous formulation of the problem).

Before proceeding with further discussion of the mechanism let us introduce some notation. Assume each country j has a cost $c_j(x)$ as a function of the number of refugee bundles it has. Let N_i be the number of bundles that have not been distributed via Vickrey auction yet after $i-1$ iterations. And let $n_{i,j}$ be the number of bundles that were auctioned to country j after $i-1$ iterations.

Then at each iteration i every country j will bid

$$b_{i,j} = c_i\left(n_{i,j} + \frac{N_i - 1}{M} + 1\right) - c_i\left(n_{i,j} + \frac{N_i - 1}{M}\right) \tag{2}$$

In other words each country will bid the marginal cost it will incur by taking that bundle, which is auctioned at the current iteration. There is no reason to bid an amount higher than $b_{i,j}$, because if that bundle is in fact allocated to the country, it will be compensated at least by the amount $b_{i,j}$. More importantly, the marginal cost a country incurs for allocating that particular refugee never increases, but may decrease over time, if the mechanism continues further. Because at each iteration N_i decreases thereby decreasing marginal costs of countries $c_i\big(n_{i,j} + \frac{N_i-1}{M} + 1\big) - c_i\big(n_{i,j} + \frac{N_i-1}{M}\big)$. Thus, the country never loses by bidding $b_{i,j}$. However, if he bids amount higher than $b_{i,j}$ its chances of winning the auction decreases. Bidding anything lower than $b_{i,j}$ is also not reasonable. One may wish to bid lower than $b_{i,j}$ if they believes there is another iteration in the future and his costs will decrease as N_i decreases allowing him to gain profit. However, countries do not have information about the number of remaining iterations. If the current period is the last one there is no reason to incur costs, so no country will bid lower than $b_{i,j}$.

This mechanism allocates all the refugees and is *budget balanced*. It is also *"strategy proof"* in a sense that at each iteration countries will bid their true marginal costs of allocating a bundle as of the current state. And it also *allocates refugees efficiently* in some way, by allocating as many refugees as possible, until the budget limit is reached, to the countries that have lowest marginal costs as of current stage. The mechanism is not fully efficient, but it allows to obtain some efficiency with the limited budget and allocates all of the refugees. Finally, this mechanism may results in the distribution of smaller number of refugees compared to the previous mechanism given exactly the limit on the budget, because initially distributing refugees uniformly across countries results in higher marginal costs. Thus, every bundle of refugees is auctioned using more funds than in the previous mechanism.

4.3. VCG with economic bads

In this model we try to implement the VCG mechanism, but by auctioning off economic bads rather than economic goods. Therefore each country's bid represents not how much they are willing to pay for a refugee, but rather how much they want to be compensated for taking one. Each country then reveals their cost function $c(x)$ that represents their cost - or how much they would want to be paid - for hosting x number of refugees. We treat x as a discrete good - the total amount of refugees is represented as bundles of increasing amounts (for example if there are 1000 refugees to be allocated, we would offer bundles of 100, 200, 300, ... , 900, 1000; and each country would provide their cost for each bundle). This representation allows us to capture the increasing marginal cost of refugees while at the same time auctioning them all off in just one iteration. We then try to distribute the refugees between member states in a way that minimizes the total cost. Each state can receive only one bad (or bundle): if country A for example bids: $c(100) = 100, c(200) = 300$, and we want to allocate 200 refugees to them, we need to compensate them 300, rather than selling them two bundles for a 100 each (because due to increasing marginal cost the second 100 would be more costly than the first ones). The constraints under which we are minimizing the total cost are then that no country should be allocated more than one bad, and that once the total amount of refugees (rather than total amount of bads/bundles) has been allocated, the auction would end.

To determine the payment that each country would receive if their bid was successful, we use VCG mechanism. We claim that this would be strategy proof, since the country would be compensated the externality it imposes on other member states if it was to not participate in the auction. This follows from the general proof of VCG truthfulness, with the main difference that rather than maximizing utility as is in the general VCG, in this case agents minimize disutility. The total utility per country would be the difference between the payment the country receives and the cost of being allocated a refugee:

$$u(j) = \sum_{i!=j}(v_i(\theta_i', o_{-j}) - v_i(\theta_i', o)) - v_j(\theta_i, o) \tag{3}$$

Each country then cannot affect the first term of the equation: $v_i(\theta_i', o_{-j}$ since this is the best possible outcome when the country is not participating. In order to maximize utility then it needs to minimize:

$$u(j) = -\sum_{i!=j} v_i(\theta_i', o) - v_j(\theta_i, o) \tag{4}$$

This is equivalent to saying it needs to maximize the opposite term (as is the case in the general VCG): it is only minimized when $\theta_i' = \theta_i$. The state therefore has incentives to report their true valuation when they reveal their cost functions: the mechanism is strategy proof.

In order to implement this mechanism we design a linear program, that aims to minimize the total cost under the constraints of auctioning off no more than the refugees we have, and no country receiving more than one bundle of refugees.

Let i denote total number of bundles, and j denote total number of countries,

then $x_{i,j} = (0, 1)$ denotes whether country j received bundle i

$b_{i,j}$ represents the bid country j puts on bundle i

n_i is the number of refugees per bundle i

Min $\sum_i \sum_j (x_{i,j} * b_{i,j})$

s.t. $\sum_i \sum_j (x_{i,j} * n_i)$

$\sum_i (x_{i,j} <= 1)$

To summarize, in this mechanism then we use VCG to determine the true cost functions of countries, and then the LP to minimize the total cost. The payments per each country will be provided from a common pool of resources: the EU refugee fund. While in reality this fund is limited, we assume that it can be expanded if necessary, by raising resources from member states the same way any other fund is financed. We also argue that using a model assuming an unlimited budget is a fair one: countries participating in the VCG auction will be revealing their true costs, therefore they should be compensated that amount of money.

5. Matching Refugees to Countries

Once refugee quotas are established for each state the next step is to match refugees to countries based on the preferences of both. Countries are assumed to have preferences on refugees' countries of origin, while refugees have preference over the member countries they are matched to. Matching is implemented in the following way. First, refugees rank EU states they want to be matched to based on their preferences, and EU states rank refugees based on the countries of their origin, order of refugees coming from the same country is determined randomly. Second step is then to match the refugees to the EU member states by applying one of the following matching mechanisms proposed by Abdulkadiroglu and Sonmez [3].

5.1. Gale-Shapley mechanism

Step 1: Every refugee proposes to his/her first choice, and every state tentatively assigns places to its proposers one person at a time following its preferences over refugees. Remaining proposers are rejected.

And generally at

Step k: All the refugees that were rejected in the previous step propose to their next choices. Every state considers its new proposers together with the refugees it has been holding and tentatively assigns seats to refugees one at a time following their rank order. Remaining proposers are rejected.

The mechanism is terminated when no refugees are rejected and all refugees are assigned to their final tentative assignments.

Gale-Shapley mechanism is strategy-proof and stable, that is there is no unmatched pair of a refugee and a state, where both prefer each other to their assignments. However, the mechanism does not always output Pareto efficient allocation.

5.2. Top trading cycles mechanism

By contrast, top trading cycles mechanism is Pareto efficient and strategy-proof. However, it does not always return a stable outcome. The mechanism is implemented in the following way.

Step 1: To each country assign a counter that shows the number of remaining places in that country. Initially for each state its counter equals to its established quota. Each refugee points to its most preferred country and each country points to its most preferred refugee. Since the number of both refugees and states are finite there will be at least one cycle, which is an ordered of distinct refugees and states $(r_1, s_1, r_2, s_2, ..., r_k, s_k)$ with r_1 points to s_1, s_1 points to r_2,..., s_k points to $r-1$. Each refugee and state can be part of at most one cycle. Then the mechanism assigns every refugee to the state it is points to and removes those refugees. Also, counters of the states that were assigned a refugee is decreased by one. A state is removed if its counter becomes zero. Counters of other states do not change.

Generally at

Stage k: Every remaining refugee points to its next preferred state and every remaining state points to its next preferred refugee. At least one cycle exists, and each refugee in the cycle is assigned to the state it is pointing to and removed. Counters of those states decrease by one, and any countries with zero counters are eliminated.

Both of the above matching mechanisms are strategy proof, thus refugees and states will reveal their preference truthfully. Also one of the algorithms perform better in terms of Pareto efficiency and the other does better in terms of stability. However, Gale-Shapley is the one which is more relevant to matching refugees to states, because it comes up with assignments that are preferable by both states and refugees. By contrast, in top trading cycles mechanism refugees have higher chances of being assigned to their most preferable choices if they are highly ranked by some states, but not necessarily to the states they are assigned to. Thus, it may assign a refugee to a state even if he/she is the least preferable refugee of that state.

5.3. Matching with gender quotas

In order to account for countries' preferences better, we propose using a matching with quotas algorithm. Both the Gale-Shapley mechanism, and the Top trading cycle one can be easily modified to adjust for countries imposing quotas (in this case we are considering gender quotas) on the type of refugees they would like to receive. We show how the Gale-Shapley algorithm can be modified in order to consider countries' preferences over the gender of refugees:

Step 1: In this step, each refugee proposes to the country of their highest ranking. The countries then tentatively agree to take in refugees one at a time, based on their ranking, and once the quota of a specific type fills, all the proposers from that type are rejected, and the assignment proceeds with refugees from the other type (gender in our case).

Step k: In the general case, if a refugee was rejected from their top choice country, they attempt to get allocated to their next best option. Each country then, considering the refugees it has been holding on to tentatively and the new proposing refugees, and again tentatively assigns spots one at a time. Once a gender quota is filled, the rest of the refugee applicants form that gender are rejected, and the mechanism continues for the other quotas.

6. Conclusion

The problem of allocating refugees between European Union members is one of growing importance and urgency. The issue of resettling the refugees is being constantly discussed and member countries often disagree on the the methods proposed. We offer two models that we believe will better allocate refugees than the current distribution key being used, since they will capture the true cost of refugees: both the economic one, which is accounted for in the EU distribution key, and the social one: how each country feels about taking in refugees. A major limitation of our models however is the fact that we do not consider the cost of transporting refugees between countries, and this might take away some of the efficiency of the mechanisms we propose: if the cost of country A for example is a bit larger than country's B cost, but the distance between them and thus the transportation cost is sufficiently large as well, it might be more efficient if the refugee remains in country A. There also might be some political costs in terms of auctioning off the refugees and treating them throughout the process as economic bads, which we are not accounting for. We are also assuming that states behave rationally and attempt to maximize utility, and that there are no collusions between them.

We propose two main models for resettlement: one considers a cap on the budget available, while the other one does not. An interesting proposition for further research on the topic could be estimating the efficiency loss due to putting a limit on the budget available. Moreover, the optimality of the VCG mechanism needs to be further explored, as needs to be efficiency of the uniform redistribution mechanism. However, we hope that this paper has offered two possible solutions to what currently seems as an unsolvable crisis.

References

[1] J. F.-H. Moraga, H. Rapoport, Tradable refugee-admission quotas and eu asylum policy, CESifo Economic Studies 61 (3-4) (2014) 638–672.

[2] J. S. You, Optimal vcg mechanisms to assign multiple bads, Games and Economic Behavior 92 (2015) 166–190.

[3] A. Abdulkadiroglu, T. Sonmez, School choice: A mechanism design approach, The American Economic Review 93 (3) (2003) 729–747.